Transmitter Fourth-Harmonic Interference at the Mars Station

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Measurements made at the Goldstone Mars Station (DSS 14) by various experimenters have indicated the presence of a relatively strong X-band fourth-harmonic level in the X-band receiver. Results of measurements on typical transmitters support this possibility. An X-band fourth-harmonic filter has now been installed in the microwave system at DSS 14 to reduce the radiated interference. This article reports on measurements of the effectiveness of the X-band fourth-harmonic filter.

I. Introduction

Observations have been reported of interference signals in the X-band receiver which are at the appropriate frequency to be attributable to the fourth harmonic of S-band. Recognizing that transmitters are usually operated in saturation, and considering the power levels involved, it is not surprising that fourth-harmonic signals are present in the waveguide system.

In the system design phase of development of the Block IV receiver, the possibility of fourth-harmonic interference was recognized because the 880/221 transponder ratio is very nearly harmonically related. There was no reliable information on the harmonic output of the klystrons at that time. Furthermore, the subnet was not equipped with X-band receiving capability, nor was there a suitable far-field receiving location. Consequently, the existing transmitter harmonic filters were designed using best engineering judgment unconfirmed by experimental data. These filters are low-pass absorptive-type units with approximately 50 dB attenuation at X-band.

Recently a device for measuring the X-band fourth-harmonic content of signals in a waveguide system has been developed with supporting research and technology (SR&T) funds (Refs. 1 and 2). Some preliminary measurements have been made using this device which will provide further insight into the spectral content of klystron signals.

The Mariner Venus Mercury 1973 (MVM'73) mission employed an X-band maser having a narrow bandwidth (15 MHz), centered well away from the fourth-harmonic of the uplink. However, researchers still reported the existence of a potentially interfering X-band fourth harmonic. An X-band fourth-harmonic filter was therefore procured and installed at DSS 14 to enhance MVM'73 data. The X-band receive only cone having a maser bandwidth of nominally 50 MHz has recently been installed, re-emphasizing the X-band fourth-harmonic interference problem. This article reports on the effectiveness of the X-band fourth-harmonic filter at DSS 14.

There are two factors that could create problems. The first is ranging sideband power. When the S-band uplink is modulated by ranging code, 500-kHz sidebands are generated. These sidebands will also appear on the fourth harmonic. The potential problem here is that these sidebands could be of significant amplitude, 38 MHz below the fourth harmonic, and therefore create interference in the X-band downlink. Careful selection of frequencies could not protect against this form of interference because of the effect of doppler.

The second concern is that fourth-harmonic carrier level in the X-band receiver could be of sufficient level, when radiating at high power, to create saturation conditions. Several researchers have reported levels that were approaching the upper limit of the receiver and maser.

II. Measurements

The basic philosophy was to establish a set of baseline measurements with the X-band fourth-harmonic filter installed. These measurements were then repeated for the system operating without the X-band fourth-harmonic filter. Areas of consideration were receiver saturation, maser saturation, inband interference from ranging sidebands, interference with telemetry data, and location of the source of the fourth harmonic. The following measurements were made to develop a baseline:

Fourth-harmonic leakage

Fourth-harmonic vs. transmitter level

Ranging sideband levels

Maser gain with/without transmitter on

Maser operating temperature with/without transmitter on

AGC level with/without transmitter on

These measurements were made using the 20-kW transmitter with the X-band fourth-harmonic filter installed and then repeated with the filter removed for both the 20-kW transmitter and the high-power transmitter operating at 300 kW. All measurements were made at channel 9 (2111.6 MHz) uplink, since this frequency would produce a fourth harmonic (8446.4 MHz) slightly above X-band channel 33, which is on the edge of the passband of the X-band receive only maser. Figure 1 indicates the relative location of channels 9 and 33 downlink as well as the location of the channel 9 uplink fourth harmonic in the XRO maser passband.

The measurement of fourth-harmonic leakage consisted of a series of measurements designed to identify leakage paths other than the primary transmitter feedhorn-to-antenna-to-receiver feedhorn path. A number of paths were identified. The composite effect of these leakage signals is of the same order of magnitude as the primary path when the X-band fourth-harmonic filter is installed. Any improvements in X-band fourth-harmonic leakage over the levels obtained with the X-band fourth-harmonic filter installed will have to involve abatement of leakage via these paths.

Fourth-harmonic level vs. transmitter level consisted of measurements directed toward determining the effect of transmitter saturation on the X-band fourth-harmonic level. Figure 2 shows the relative strength of the X-band fourth harmonic in the receiver as a function of transmitter power. It is apparent that the level is a nonlinear function of transmitter power. This is to be expected at high transmitter levels, since the transmitter operates in a saturated mode at high power levels. The measurements of Fig. 2 were made with the klystron power supply level fixed at that required for the 20-kW saturated mode. The drive power was used to adjust power output level. The nonlinear characteristic at 1 kW was not expected, but it demonstrates the uncertainty of extrapolating measured data to other conditions. Furthermore, power level is not the only parameter of concern. Measurements by other experimenters have shown that fourth-harmonic levels generated by the 100-kW transmitters are frequency-dependent. X-band fourth-harmonic levels from the high-power transmitter were not measured until after removal of the X-band fourth-harmonic filter. Fourth-harmonic level due to the high-power transmitter operating at 300 kW was approximately −80 dBm, whereas the 20-kW transmitter generated about −87 dBm. The uncertainty of the levels is approximately ±6 dB. That is, the results for identical conditions were found to vary from day to day or week to week by ±6 dB. This is typical of leakage signals.

Ranging sideband measurements consisted of tuning the receiver to the selected sideband and recording the received signal level. Upper sidebands were not measured, since these are attenuated by the passband of the maser.

Three groups of sidebands were identified for investigation. Close-in sidebands (1st–9th) indicate the shape of the modulation envelope. Sidebands about 12 MHz below the fourth harmonic (23rd–25th) are in the channel 20 downlink passband. The third group of sidebands investigated were those appearing in the channel 9 downlink. These sidebands were found to be below receiver threshold even when radiating at 300 kW. More recent investigation has shown that low-pass filters in the ranging coders and in the receiver modulator attenuate the high-order components of the range code sufficiently to prevent same-channel downlink interference.

Figure 3 shows the X-band fourth harmonic and two groups of ranging sidebands, as observed while radiating at 13 kW. Each spectral line is drawn with two arrowheads, indicating the signal level with and without the X-band fourth-harmonic filter installed. It is evident that the X-band fourth-harmonic filter is effective in reducing the level of fourth-harmonic and fourth-harmonic ranging sideband levels in the receiver. The close-in sidebands are reduced almost to receiver threshold. However, the level of ranging sidebands in the channel 20 downlink (~8423 MHz) produced by the modulation on the channel 9 uplink are not reduced to insignificance. These sidebands, with the presence of doppler on the downlink, would definitely create interference in channel 20. The channel 9 uplink/channel 20 downlink investigation was selected from among the possible Viking channel allotments because it places the fourth harmonic closest to the downlink, thereby constituting the worst case. Other projects may have different channel assignments and therefore require more data if S-band ranging and X-band telemetry are to be scheduled simultaneously. It is safe to say, however, that same-channel uplink/downlink will not experience ranging sideband interference.

The last three entries in the list of baseline measurements pertain to receiver saturation caused by X-band fourth-harmonic interference. Maser gain and receiver gain (as indicated by AGC voltage), at channel 9, were measured with and without the X-band fourth-harmonic filter installed. However, no discernible effect was found. Maser operating temperature at channel 9 in the presence of the fourth-harmonic interference while radiating at 300 kW without an X-band fourth-harmonic filter did show a small increase (0.1 dB). The receiver and maser cognizant design engineers agree that X-band fourth-harmonic interference signals of the magnitude reported here are very close to that required to produce saturation. The slight observed rise of system temperature may signal the beginning of saturation.

III. Conclusion

At DSS 14 it is evident that an X-band fourth-harmonic filter is required. This conclusion is predicated on the magnitude of the fourth-harmonic interference in relation to the saturation characteristics of the maser and receiver and the fact that our tests were limited to 300 kW, whereas the planned capability is for 400 kW. Furthermore, these test results were found to be highly variable, as is the nature of leakage signals.

Extrapolating these results to other deep space stations which have different transmitters is tenuous at best. Results of tests at DSS 63 in Madrid indicate that the X-band fourth-harmonic level is below receiver saturation by about 10 dB. The S-band ranging with X-band telemetry restriction probably holds at all stations. With a 10-dB margin between measured interference and receiver saturation, further tests should be conducted to insure that different conditions will not cause saturation. Evidence at DSS 14 indicates that different frequencies, transmitter saturation conditions, and perhaps antenna configuration affect X-band fourth-harmonic level.

References

1. Smith, R. H., "Fourth Harmonic Analyzer," in *The Deep Space Network Progress Report 42-20*, pp. 121–123, Jet Propulsion Laboratory, Pasadena, Calif., April 15, 1974.
2. Grigsby, Y. L., "Automation of Data Gathering and Analysis for the Fourth Harmonic Analyzer" in *The Deep Space Network Progress Report 42-26*, Jet Propulsion Laboratory, Pasadena, Calif., April 15, 1974.

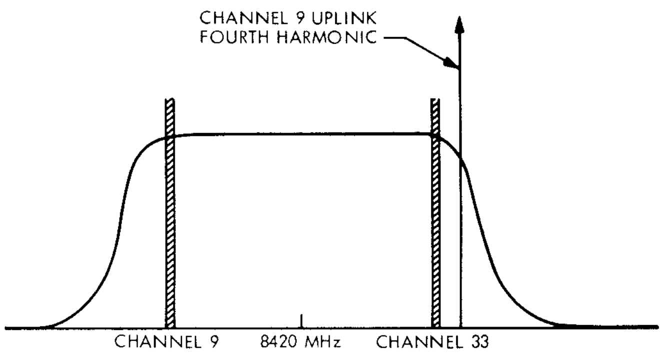

Fig. 1. XRO maser passband

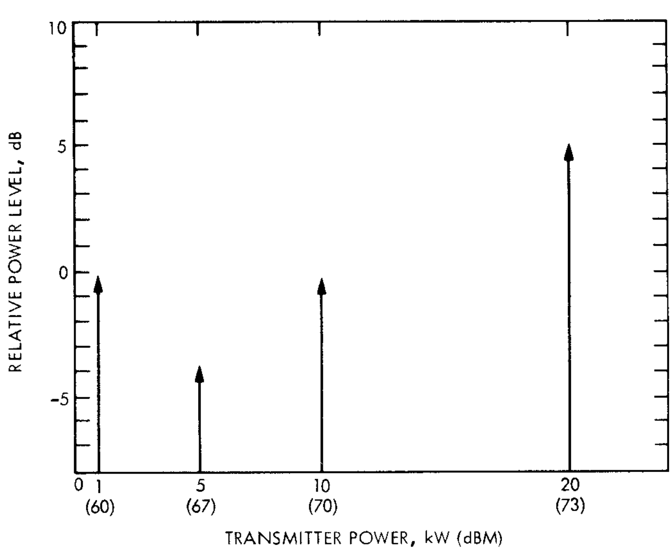

Fig. 2. Relative level of fourth-harmonic leakage vs. transmitter power

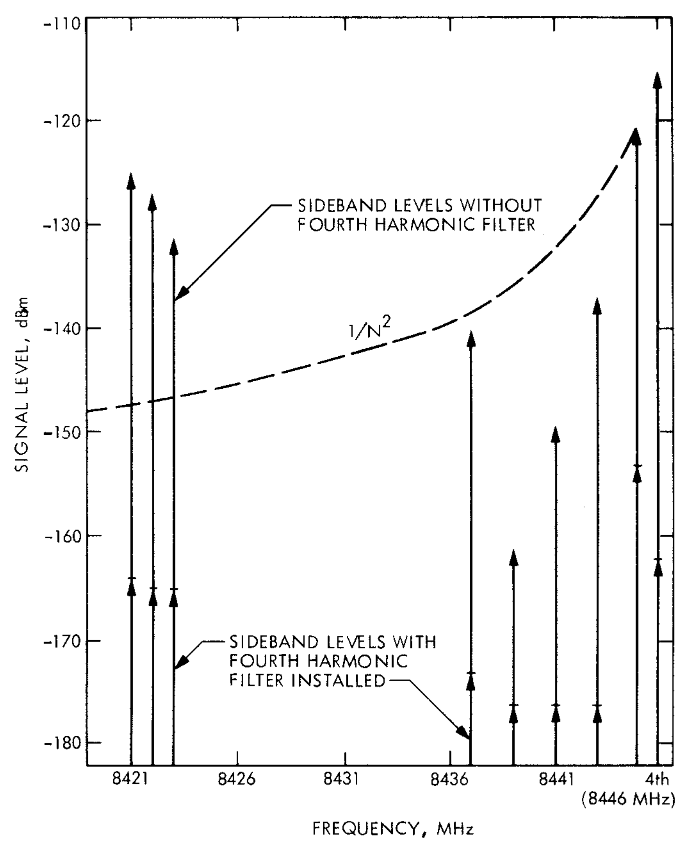

Fig. 3. Low-side ranging sidebands